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In This Issue

A Method for Designing Non-Rigid Pavements for Highways and Airport Runways

Crushed and Broken Stone in 1939

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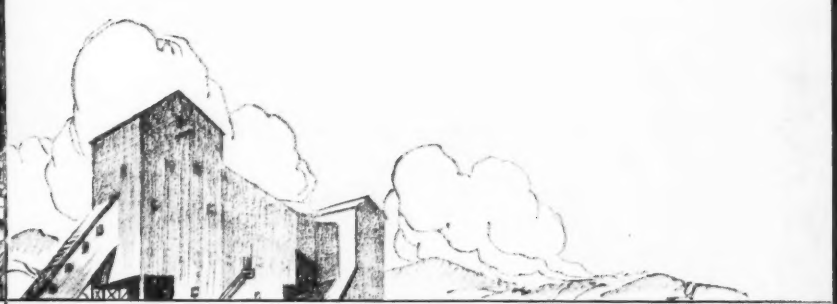
Transportation—Its Use and Misuse in Peace and War



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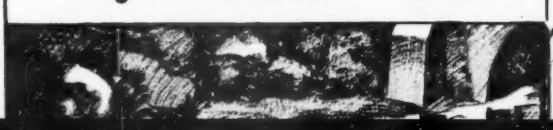

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Contents

Page

A Method for Designing Non-Rigid Pavements for Highways and Airport Runways
—A. T. Goldbeck - - - - - 3

Crushed and Broken Stone in 1939
—Oliver Bowles and M. S. Jensen - 14

An American Primer
—Philip D. Reed - - - - - 16

Transportation—Its Use and Misuse in Peace and War
—M. J. Gormley - - - - - 21

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THE
CRUSHED STONE JOURNAL
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A Method for Designing Non-Rigid Pavements for Highways and Airport Runways

By A. T. GOLDBECK
Engineering Director,
National Crushed Stone Association

• For many years engineers have sought a method for determining the proper thickness of the flexible or non-rigid road to support given wheel loads. The method here suggested is founded on tests, is simple to apply and should be extremely useful in designing the non-rigid type of road and runway surface.

Introduction

AT THE outset let it be emphasized that the thoughts expressed in the present article are tentative and may have to be revised as additional knowledge on the design of the non-rigid road becomes available. It is believed, however, that the method of design herein described will enable the practical highway engineer to determine the thickness of a non-rigid road surfacing required to safely, yet economically, support a given wheel-load.

By the non-rigid type of road surfacing is meant that type which ordinarily is not thought capable of developing resistance to bending under load. When a wheel-load is imposed on the surface, it transmits that load to the underlying subgrade through areas which increase in size as the subgrade is approached and, consequently, the thicker the layer of non-rigid surfacing material, the greater becomes the area on the subgrade which is subjected to pressure and the smaller becomes the maximum intensity of subgrade pressure. This pressure is not of uniform intensity on the subgrade, but is of highest intensity directly under the center of the contact area of the tire.

Included in the non-rigid type are the various forms of macadam and gravel roads, bituminous macadam and bituminous concrete and also, in all probability, most forms of stabilized bases. Although these different forms of the non-rigid road are probably not equally effective in carrying traffic loads, in the present discussion no attempt is made, numerically, to differentiate between them. It is thought by some engineers that certain of these types, such as bituminous concrete, by virtue of their cohesion, may develop a considerable amount of resistance to bending, especially under moving loads, and if this is true they might have to be classified as semi-rigid roads. However, the present design method applies to them, also.

A number of theories have been presented in the past for designing the non-rigid road, all of them requiring that certain experimental constants be determined in order that the theory might be applied to practical design. The present method is a simple generalization of the National Crushed Stone Association subgrade pressure test results into a design theory which may be applied in a practical manner, provided only that a determination be made of the bearing value of the supporting subgrade.

How Subgrade Pressures are Distributed

In the November-December, 1939, issue of the CRUSHED STONE JOURNAL and also in the Proceedings of the Highway Research Board for 1938, Part II, page 66, there appeared an article by the present author entitled "Studies of Subgrade Pressures Under Flexible Road Surfaces." It was shown in that article that the pressures on the subgrade produced by elliptically shaped bearing blocks, having areas identical with the areas of contact between pneumatic tires and the road surface, are not uniform pressures, but, to the contrary, they are pressures which are of highest intensity directly under the center of application of load and are distributed in accordance with a bell-shaped curve over a considerable area on the subgrade directly under the load. The longitudinal distribution due to a motor truck wheel-load may extend over a total length of four feet or more with a somewhat lesser distribution laterally because of the elliptical shape of the area of contact. Under a large airplane tire, the pressure distribution is of even wider extent.

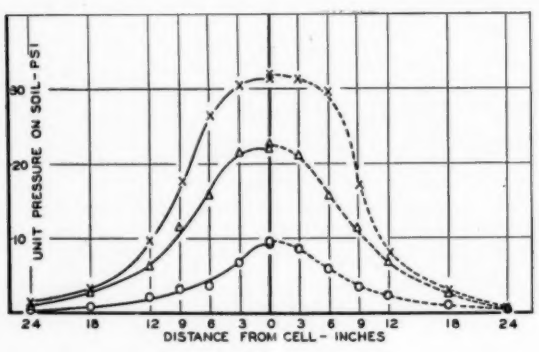

FIGURE 1

In Fig. 1 are shown typical curves of pressure distribution on the subgrade for 4000, 8000 and 12000 pound, single tire, truck wheel-loads, respectively, as transmitted through 8 inches of very stable limestone screenings. The maximum pressure under the center of the wheel will be greater or less than the pressures shown in Fig. 1, depending in part on such matters as:

1. The thickness of the non-rigid surface.
2. The stability or rigidity of that surface.
3. The magnitude of the wheel load.
4. The area of the imprint of the tire.
5. The load-supporting value of the subgrade.

As above stated, a thick, stable but non-rigid layer will transmit a wheel load over a larger area of the subgrade than a thin layer, and consequently the maximum subgrade pressure intensity will be less under the thick layer. A very stable layer will transmit the load over a wider area than a less stable layer and this likewise will affect the maximum subgrade pressure intensity. A heavy wheel load will increase the pressure intensity as compared with that due to a light wheel-load. Finally, the supporting value of the subgrade has some effect on the maximum pressure intensity transmitted to it. A very rigid subgrade will be subjected to a higher central maximum pressure than that imposed on a rather soft subgrade material.

Fundamental Conceptions in Design Theory

As a fundamental thought in the design theory now presented, it seems reasonable to assume that the thickness of the non-rigid surface should be such that the maximum pressure produced on the subgrade directly under the center of the wheel will not exceed the bearing capacity of the subgrade material in its least stable condition. If the pressure intensity produced by the load does exceed the bearing capacity of the soil, it will yield unduly under the pressure applied and the flexible surface, through lack of sufficient subgrade support, will be subjected to excessive bending and its integrity will be destroyed. It is sometimes safe to overstress a material at a given point without danger of failure, whereas failure may occur if the overstress occurs over a wide area. It will be considered here that overstress, even at a single point, is undesirable.

Accordingly, let the following rule be set down as a safe one to follow:

The maximum pressure intensity on the subgrade produced by the wheel-load should not exceed the bearing capacity of the soil.

Bearing Capacity of Subgrade Soil

The above rule immediately brings up the question, What is meant by "Bearing Capacity"? The soil composing the subgrade acts, in part, elastically

and, in part, as a plastic material. It is somewhat elastic in the sense that when a load is applied and again released there is some recovery from the indentation produced by the load. On the other hand, it is plastic since, as a rule, even the smallest load will produce a certain amount of permanent indentation or deformation. If a bearing block is placed on the subgrade and a small load is applied, that block indents the soil and if that load is retained, the indentation will increase in amount. An addition to the load will cause additional indentation and if the load is retained for a short time that indentation will continue to increase. It is known that the indentation produced by a bearing block subjected to load is governed not only by the magnitude of the load applied, but also by the duration of load application and by the size of the bearing block. A large bearing block when subjected to load of a given unit value will indent the soil to a greater

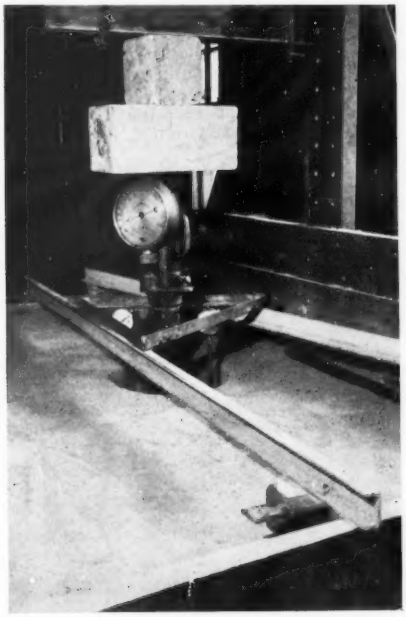

FIGURE 2

Making load-indentation (bearing value) test on subgrade. Bearing block, circular, with 100 sq. in. of area. Indentation is determined with two dials reading to 0.001 in.

degree than a smaller bearing block subjected to that same pressure intensity.* All of these matters are important in considering how to determine the bearing capacity of a subgrade for supporting the flexible or non-rigid type of road.

*The Supporting Value of Soil as Influenced by Bearing Area, by A. T. Goldbeck and M. J. Bussard, Public Roads, January, 1925.

As indicated above, the pressure intensities on the subgrade are distributed over a restricted area under the non-rigid road and they are distributed over a still wider area under a road of the more rigid type such as concrete. If the bearing capacity of

4" Screenings on 18" Subgrade
Moisture:—Screenings 3.4
Subgrade 9.4

Load-Indentation Test on Subgrade

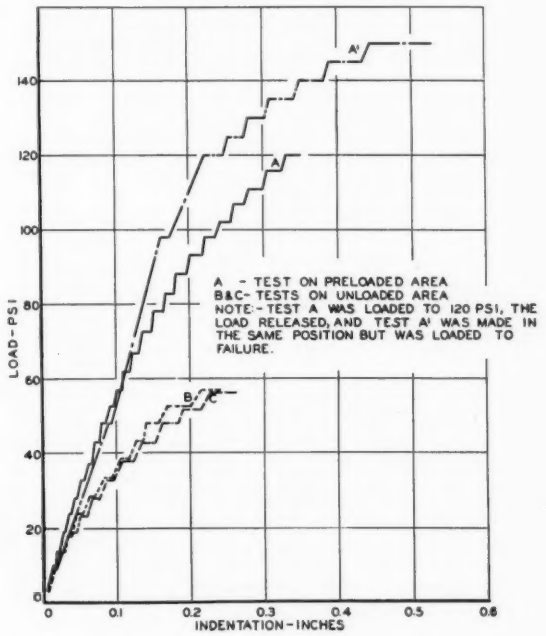

FIGURE 3

the subgrade under a concrete road were to be determined it would seem reasonable therefore that a larger bearing block be used than in the case of the flexible type. It will be seen from the pressure curve, Fig. 1, that the highest pressures are confined within a relatively small area and to closely approximate the actual subgrade pressure conditions, a bearing block should be used for determining the subgrade bearing capacity which will not deviate too widely from the size of the high pressure area. In the National Crushed Stone Association tests a circular bearing block having 100 square inches is used for determining the bearing capacity of the subgrade and experience with the determination of subgrade resistance in our laboratory has been obtained with a bearing block of that size. A hydraulic jack, frequently calibrated, is used for applying load to the block and dials reading to 1/1000 in. are used

for determining the indentation or movement of the block into the subgrade. A typical view of this apparatus is shown in Fig. 2.

In Fig. 3, Curve A, is shown a pressure-indentation curve made by applying load in increments of 500 pounds total load, or 5 psi. A one-minute time interval elapsed between each load application

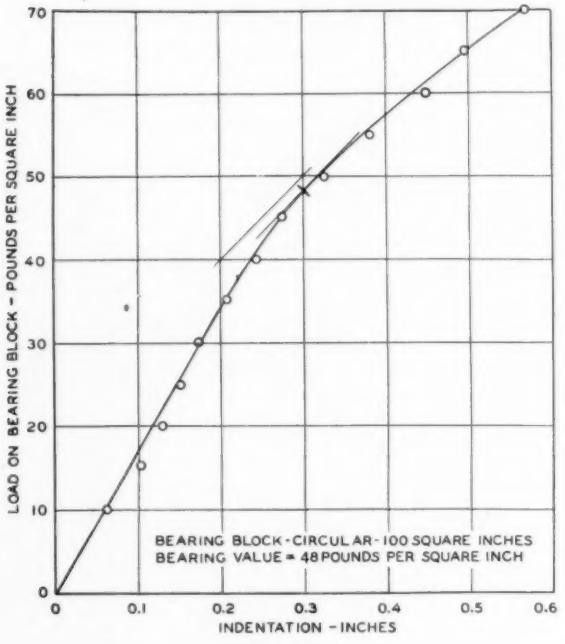

FIGURE 4

BEARING VALUE TEST ON SUBGRADE

and this accounts for the stepped appearance of the curve. Having obtained this curve, the question arises, What may be considered a safe bearing value for the soil? It will be noted that the curve starts from the point of zero origin and proceeds more or less in a straight line and at about 60 psi load it begins to deviate from this straight line in the form of a curve. This deviation means that after a pressure of 60 psi is reached, the soil yields more rapidly under the same increment of load and because of this more rapid yielding, the question arises whether to load that particular soil with a pressure in excess of 60 psi.

Had the soil been softer than that used in this particular test, such, for instance, as was the case in the test shown in Fig. 4, the yielding of the soil under increasing load would be much greater than in the first test and this brings up the question, How much yielding of the soil is permissible? If it yields too much, the road surfacing is subjected to excessive bending and disruption may take place. It seems logical to limit the amount of indentation permissible and in soils of a yielding nature, the bearing capacity should be determined for that amount of indentation of the bearing block which is considered the maximum permissible. No very definite information exists on what that maximum indentation might be, but judgment would indicate that ½ in. should not be exceeded, provided that at that amount of indentation, the ratio of increase in unit pressure to increase in indentation is not too low. If this ratio is low there will be a large increase in indentation under a small increase in load and the soil may be close to failure. The problem is perplexing and a decision as to what constitutes permissible bearing value needs judgment in interpreting bearing value tests.

It is suggested, tentatively, that for determining the bearing value of the subgrade, the following procedure be used:

Apply load on a 100 sq. in. bearing block in increments of 5 psi, allowing one minute to elapse between each increment. A calibrated hydraulic jack of 20,000-lb. capacity is useful for this purpose. By the use of two suitable dials reading to 0.001 in., obtain the average indentation of the bearing block into the soil for each increment of load.

The question of condition of moisture or compaction of the subgrade when the test is made must be left to the judgment of the investigator. It would be desirable, if possible, to bring about the most unfavorable conditions which will probably ever exist under the finished surfacing.

Plot the load indentation curve thus obtained and from this curve obtain the bearing capacity at the point of ½ in. indentation of the bearing block, or at a lesser indentation determined at the point at which the ratio of pressure increase to indentation increase is equal to 100.

The above method is suggested in the hope that discussion may develop a simpler method, for use either in the field or in the laboratory. Perhaps the bearing value may be obtained with sufficient accuracy through the interpretation of suitable laboratory tests for other soil properties.

Development of Formulas for Thickness

In general, a motor truck or an airplane wheelload is applied to the surface, either through a single

tire or through a dual tire and each case must be considered separately, although the general method of approach in the development of the required formulas for thickness of surfacing in each case will be the same. Static loads will be considered at present, but if it should later develop that impact factors are necessary, this possibility will not present any difficulty. It is not believed, however, that impact is any longer very important in its effect on the non-rigid surface, with present-day, low pressure tires. It is true that higher than static loads have been shown to exist under moving motor truck tires and also during the landing of an airplane. However, owing to the rapid forward motion in both cases there is doubt if the impact effect is important in causing damaging increase in subgrade deformation above that produced by static load. It has been observed that there is more likelihood of an airplane punching through a too thin surfacing when at rest than when landing. Accordingly, it is believed that the governing loads for design purposes are static wheel loads.

Single Tire Loads

As before explained, the actual pressures measured on the subgrade take the form of a curve of distribution such as shown by the curve labeled "Actual Pressure Distribution" in Fig. 5, headed "Case of Single Tire Load." An attempt to use this curve of pressure directly in the development of a practical theory of design might present mathematical difficulties. Consequently, recourse is made to the use of an imaginary equivalent uniform pressure which exists on the subgrade over an elliptical area confined within 45-degree lines drawn from the circumference of the elliptical imprint area of the tire. This elliptical area of assumed equivalent uniform pressure on the subgrade equals

$$\pi\,(L_1+T)\,(L_2+T) \quad \ldots\ldots (1)$$

and the equivalent uniform pressure, U = the wheel load divided by the area over which this assumed uniform pressure would be distributed or

$$U=\frac{P}{\pi(L_1+T)\,(L_2+T)} \quad \ldots\ldots (2)$$

From the above equation (2) the thickness of the pavement is found to be

$$T=\sqrt{\frac{P}{\pi U}+\left[\tfrac{1}{2}(L_1+L_2)\right]^2}-L_1L_2\ -\tfrac{1}{2}(L_1+L_2) \quad \ldots (3)$$

The above equation contains the quantity U, but this quantity depends on the thickness of the pavement and consequently in its present form the equation cannot be used for determining thickness. However, a number of subgrade pressure distribution tests have been made by the National Crushed Stone Association laboratory in the manner described in the article previously noted and, as a result of these

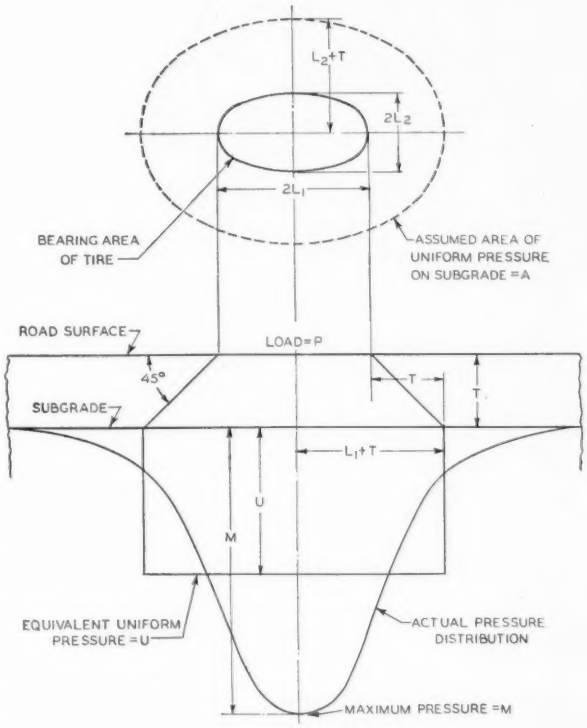

FIGURE 5
CASE OF SINGLE TIRE LOAD

tests, it becomes possible to compare the actual, measured maximum pressure with the assumed uniform equivalent pressure for a number of different test conditions. This comparison is shown in the accompanying Table I.

One might expect to find a wide variation in the ratio of maximum measured pressure to the calculated equivalent uniform pressure, depending on several conditions such as rigidity of the surfacing, its thickness and the resistance or bearing value of the subgrade. To be strictly scientific, an appropriate value "k" for this ratio of maximum measured pressure "M" to uniform equivalent pressure "U" should be used for the particular surface and subgrade under consideration. If the correct value for k were known for each particular combination of

TABLE I

RATIO (k) OF MAXIMUM SUBGRADE PRESSURE (M) TO CALCULATED UNIFORM PRESSURE (U)
k = M DIVIDED BY U

Test No.	Subgrade		Surface			Single Tire Loads, Lb.			Dual Tire Load, Lb.
	Per cent Moisture	Bearing Value psi	Type	Per cent Moisture	Thickness In.	4000	8000	12,000	8000
						Values for k			
			Stable Surfaces						
2	9.4	56	Screenings	3.4	4	1.9	2.0	...	2.8
11	9.1	70	Screenings-Emulsion	2.8	4	1.5	1.6	1.7	...
12A	8.8	60	W. B. Macadam	2.0	4	1.4	1.8	1.8	2.5
1	9.2	50	Screenings	3.8	6	1.6	1.6	1.9	...
12B	8.2	..	W. B. Macadam	1.2	6	1.0	...	...	1.0
14	10.2	48	Sand-clay-Gr.	3.3	6	2.5	2.5	2.7	2.4
13A	9.6	30	W. B. Macadam	2.0	10	2.3	3.1	2.8	2.6
15	10.3	50	Sand-Clay-Gr.	3.7	10	1.6	1.9	2.1	1.8
16	....	40	Hot. Bit. Conc.	...	4.6	2.0	2.7	2.4	2.6
13B	10.3	44	W. B. Macadam	2.7	10	1.8	2.0	2.0	2.3
10	10.8	15	Screenings	2.9	4	1.4	1.6	...	...
10A	11.5	10	Screenings	2.1	4	2.1	...	...	...
7	11.0	30	Screenings	2.8	6	...	1.3	1.4	1.4
12	10.4	29[1](-)	W. B. Macadam	1.1	6	...	2.0	2.2	...
8	10.3	49	Screenings	2.8	8	...	1.2	1.5	1.3
13	10.3	25	W. B. Macadam	1.5	10	1.6	2.1	2.2	2.2
11A	9.9	42	Screenings-Emulsion	3.8	4	1.9	2.0	2.2	...
6	8.3	100	Screenings	3.5	8	1.3	2.0	2.0	1.6
					Ave.	1.7	2.0	2.1	2.0
			Unstable Surfaces[2]						
3	10.5	44	Screenings	6.2	4	4.3	...	...	4.4
5	10.4	55	Screenings	7.0	8	4.4	5.3	...	3.2
9	10.0	40	Screenings	6.0	6	4.5	4.1	...	3.8
15B	9.5	50	Sand-Clay-Gr.	4.5	10	2.7	3.3	3.6	2.6
					Ave.	4.0	4.2	3.6	3.5

[1]At ½" indentation, the ratio of pressure increase to indentation increase is only 55 instead of desired minimum of 100. At no value of indentation was subgrade sufficiently resistant.

[2]These surfaces were purposely made unstable by the use of excessive water in their preparation.

surface and subgrade, then the desired thickness could be calculated from the following formula (4) derived by substituting for U in formula (3) its value $U = \frac{M}{k}$:

$$T = \sqrt{\frac{kP}{\pi M} + \left[\tfrac{1}{2}(L_1 + L_2)\right]^2} - L_1 L_2 - \tfrac{1}{2}(L_1 + L_2) \quad \ldots (4)$$

The above formula can be used for cases in which the wheel load is carried on a single pneumatic tire. For convenience of reference, the above letters represent the following values:

T = thickness of non-rigid surface required

P = maximum wheel load on a single pneumatic tire

k = ratio of $\frac{M}{U}$ = maximum pressure intensity on subgrade (assumed equal to subgrade supporting value) divided by U, the calculated equivalent uniform pressure on subgrade.

L_1 = ½ major axis of ellipse of tire contact area

L_2 = ½ minor axis of ellipse of tire contact area

If the tire is a motor truck tire then $L_1 = 2L_2$ and equation (4) becomes

$$T = \sqrt{\frac{kP}{\pi M} + \left(\frac{L_2}{2}\right)^2} - \frac{3L_2}{2} \quad \ldots (5)$$

In the course of time perhaps additional experiments will permit of stating exactly what value to assign to "k" for each kind of road surfacing material or other influencing variable. If the surfacing material is rigid, k will be smaller than if it is of a material which might at times become softened by

water. Thus, a surfacing of well interlocked macadam or well bound bituminous macadam or bituminous concrete may well have a smaller value for k than a sand-clay or a clay-bound gravel base. The former types are unaffected by water; the latter can be so affected as to permit of high pressure intensity on the subgrade.

It should be remembered that certain so-called rational theories for design in other fields of engineering have been devised as the most convenient, though not necessarily the most exact, generalization of the supporting test data. They are justified by their simplicity in application and by the reasonable and safe results they produce. They provide a practical working basis for design which may be refined and corrected as more information becomes available. It is with such thoughts as these in mind that the present design method is proposed, —not as something final and conclusive, but rather as a method which should be immediately useful, and which may need revision in due course.

At present and until more exact values are ascertained, if indeed these are necessary from a practical standpoint, recourse is had to the values for k established by the current National Crushed Stone Association tests and given in Table I. Although these values show some range depending on the variables in the test, still, for those surfaces which are stable, the average value for k is not far from 2 and it is believed that a universal value of $k = 2$ is sufficiently accurate for general design purposes as applied to most stable surfaces and to loads carried on single tires. It is true that values higher than 2.0 are found in the table, but here judgment must be used. Some of the surfaces shown undoubtedly are not as rigid as would be the case with similar surfaces prepared under actual construction conditions. This statement applies to the waterbound macadam and to bituminous concrete. Then, too, there are certain questions of laboratory technique involved in the problem, which need not be discussed at present. The laboratory procedure presents many difficulties, but the results obtained are very illuminating and useful when interpreted with judgment and with practical construction conditions in mind. The conditions of the test are apt to make the pressure measurements too high rather than too low.

If, as shown at the bottom of Table I, the surfacing is somewhat unstable, a higher value for k must be used. This is a case which need not be considered if the surface is designed to retain its stability in spite of the presence of water. Should the surfacing be of a nature which may become unstable when wet, a higher value for k is necessary—perhaps even up to 4 or 5. But there is no reason for permitting conditions which will produce such instability.

Using a value for $k = 2$

$$T = \sqrt{\frac{2P}{\pi M} - \left(\frac{L_2}{2}\right)^2} - \frac{3L_2}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Remembering that the question of the proper value for M, the bearing value of the subgrade material, is difficult to decide, it would be unduly meticulous to insist on strict accuracy in the use of the above formula (6) and since the quantity $\left(\frac{L_2}{2}\right)^2$ has very little effect on the final thickness, it is reasonable to eliminate this value and finally there results:

$$T = \sqrt{\frac{2P}{\pi M}} - \frac{3L_2}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The above equation is applicable to single truck tires. For the benefit of those who might feel safer through the use of an impact factor, this can be introduced merely by increasing the value for P by the desired percentage.

For airplane tires it is best to use equation (4) making $k = 2$ and calculating the values for L_1 and L_2 from the known wheel-load and tire pressure. It is not strictly accurate to equate the wheel-load to the tire contact area multiplied by the tire pressure because each tire has a "supporting factor" which results in a reduced area of contact. This supporting factor varies but can be taken as 1.10 and equals—

$$\frac{\text{Actual Tire Load}}{\text{Inflation Pressure x Contact Area}}$$

However, it is probable that the use of the tire supporting factor for calculating tire contact area would savor of straining for accuracy beyond what seems possible in a problem of the nature under consideration. Hence, it will be considered sufficiently accurate to ignore the existence of a "supporting factor." This factor is mentioned, however, for those who may wish to use it for more accurately calculating the contact area.

The width of the elliptical imprint or contact area of an airplane tire may be taken as equal to the nominal overall width of the tire ($2L_2$); then, since the tire contact area $= \pi L_1 L_2$,

$$\pi L_1 L_2 \text{ x inflation pressure} = \text{Actual Tire Load} \quad (8)$$

From the above equation (8), L_1 may be obtained and equation (4) may then be used to obtain the required thickness of the runway if the subgrade supporting value (M) has been determined using the methods described.

Dual Tire Loads

Most heavy wheel loads on motor trucks are carried on dual tires rather than on single tires and

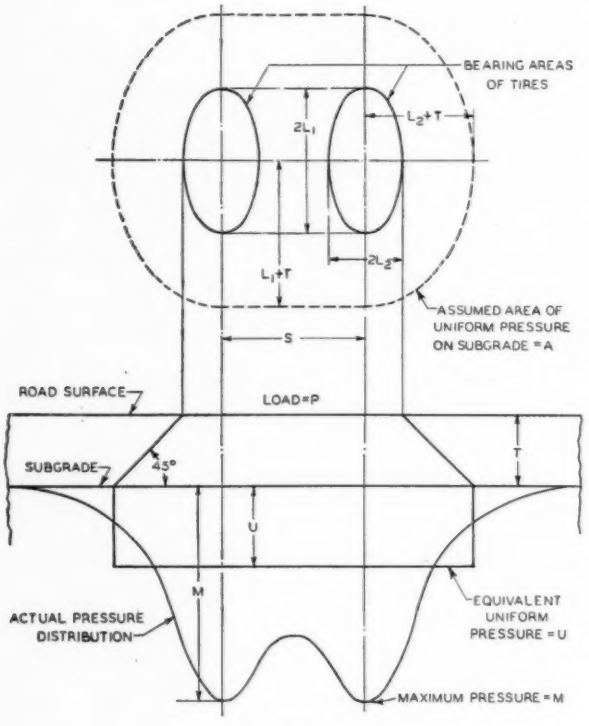

FIGURE 6
CASE OF DUAL TIRE LOAD

in the design of non-rigid pavements, the influence of dual tires is very important. A given wheel load when carried on dual tires is less severe than when carried on a single tire because:

(1) The load is spread over a wider area on the subgrade, and
(2) The tire pressure is less in the smaller tires used together.

To develop the theory of design making use of dual tires, refer to Fig. 6. The pressures, by actual measurement, are found to be distributed transversely much as shown by the curve labeled, "Actual Pressure Distribution." Here, as in the case of the single tire, it is desirable that the maximum pressure on the subgrade never exceed the bearing capacity of the subgrade and, for economy, it seems logical to make the design such that the maximum pressure approach the subgrade supporting value as determined by the method previously described.

Since mathematical complications would ensue in attempts to use the actual curve of pressure distribution, let it be assumed that the pressures are confined within an area defined by 45-degree lines sloping from the sides of the tire imprint areas and from the straight lines connecting the ends of the major axes of these areas, and shown in Fig. 6 by dotted lines. Over this area the subgrade pressures will be assumed as uniform. Had some other method of arriving at the assumed area of equivalent uniform pressures been used, the final calculated road thickness would not be altered. The use of confining lines of 45-degrees makes for a simple form of calculation and this is the sole reason for their use.

Referring to Fig. 6.

Let P = wheel load
A = area of equivalent subgrade pressure
U = equivalent uniform pressure over area A
M = maximum subgrade pressure, also equal to bearing value of subgrade
S = center to center spacing of dual tires
L_1 = half major axis of tire contact area
L_2 = half minor axis of tire contact area

$$k = \frac{M}{U}$$

$$A = 2S(L_1 + T) + \pi(L_1 + T)\ (L_2 + T)$$

$$P = AU = \frac{AM}{k} = \left[2S(L_1+T)+\pi(L_1+T)\ (L_2+T)\right]\frac{M}{k}$$

from which $$T = -\frac{B}{2\pi} + \sqrt{\left(\frac{B}{2\pi}\right)^2 + C} \quad \ldots\ldots\ldots\ldots (9)$$

where $B = 2S + \pi(L_2 + L_1)$

$$C = \frac{Pk}{M\pi} - \frac{2SL_1}{\pi} - L_1L_2$$

Referring to Table I under "Dual Tires" there will be found values for $k = \frac{M}{U}$ determined from tests by the use of the National Crushed Stone Association test bin. These results thus far are rather meager

and are seen to have considerable variation depending on the various conditions. At the present time it seems safest to be somewhat conservative in selecting any one value for k for general use. Although the average value for k obtained with stable surfaces is about 2.0 there is one value as high as 2.8. Judgment must be used in selection of the proper value to use for any particular kind of non-rigid surface. Some of the non-rigid types might permit of small values while less rigid surfaces would necessitate the use of higher values. It would seem, however, that 2.5 might be selected as a suitable value for general design use. This value is conservative and is higher than the average value of 2.0, thus far secured by pressure tests.

Some Examples of Design

Example I

Let it be required to design a non-rigid road type to carry a motor truck with a load of 8000 pounds on a single tire.

P = 8000 lb.
Tire pressure = 82.5 psi,
Contact area = 97 sq. in.

$2L_1 = 16$ in., $2L_2 = 8$ in.

M = subgrade bearing value = 40 psi

$$T=\sqrt{\frac{2P}{\pi M}}-\frac{3L_2}{2}=\sqrt{\frac{2\times 8000}{\pi\times 40}}-\frac{3}{2}\times 4=11.3-6=5.3 \text{ in.,}$$

say 6 inches.

Example II

Let the 8000 pound wheel load be carried on dual tires then—

P = 8000 lb.
Tire pressure = 69.0 psi
$2L_1 = 12$ in., $2L_2 = 6$ in.

S = 12 in.
M = 40 psi
k = 2.5

$$B=2S+\pi(L_2+L_1)=$$

$$2\times 12+\pi(3+6)=24+28.2=52.2$$

$$C=\frac{Pk}{M\pi}-\frac{2SL_1}{\pi}-L_1L_2=$$

$$\frac{8000\times 2.5}{40\times\pi}-\frac{2\times 12\times 6}{\pi}-6\times 3=$$

$$159-45.8-18=95.2$$

$$T=\frac{-B}{2\pi}+\sqrt{\left(\frac{B}{2\pi}\right)^2+C}$$

$$=\frac{-52.2}{2\pi}+\sqrt{\left(\frac{52.2}{2\pi}\right)^2+95.2}$$

$$=-8.3+\sqrt{69+95.2}$$

$$=-8.3+12.8=4.5 \text{ in., say 5 in.}$$

Example III

Assume an airplane runway is to be designed for a plane having a gross weight of 45,000 lb.; tire size 19.00 x 23; inflation pressure 63 psi; Let the subgrade resistance equal 40 psi.

The tire imprint area is approximately equal to $\frac{22{,}500}{63}$ = 357 sq. in. Actually the imprint area is known to be somewhat smaller than as above calculated, due to the "supporting factor" of the tire, but this refinement in the calculations is not warranted. The width of the ellipse of contact is approximately equal to the tire width which is 19 inches.

$$\pi\times\frac{19}{2}\times L_1=357 \text{ sq. in. } L_1=2\times\frac{357}{\pi\times 19}=12 \text{ in.; } L_2=9.5 \text{ in.}$$

Using Formula (4)

$$T=\sqrt{\frac{kP}{\pi M}+\left[\tfrac{1}{2}(L_1+L_2)\right]^2-L_1L_2}-\tfrac{1}{2}(L_1+L_2)$$

$$=\sqrt{\frac{2\times 22{,}500}{\pi\times 40}+\left[\tfrac{1}{2}(12+9.5)\right]^2-12\times 9.5}-\tfrac{1}{2}(12+9.5)$$

= about 8 inches

Similarly, calculations have been made for various truck wheel loads carried on single and on dual tires and for various airplane wheel loadings on single tires. The results of these calculations are shown in Figs. 7, 8 and 9. Tables II and III, taken from the Year Book of the Tire and Rim Association, are included for the convenience of those who may wish to make special calculations.

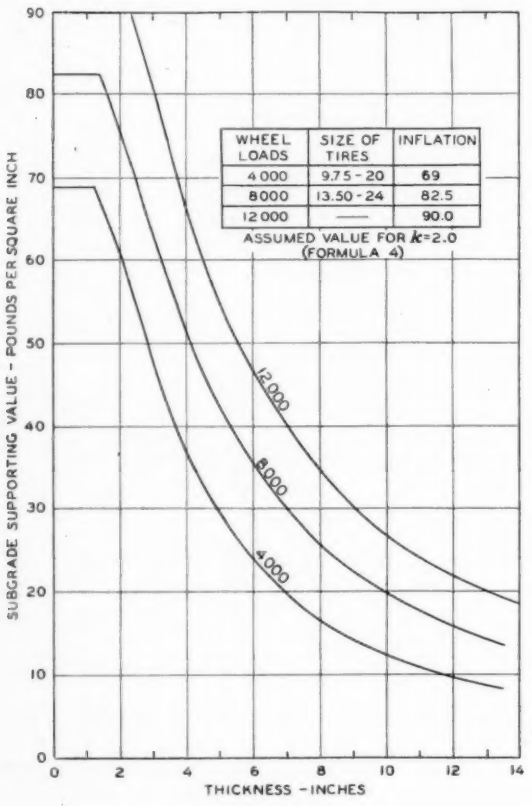
WHEEL LOADS | SIZE OF TIRES | INFLATION
4000 | 9.75-20 | 69
8000 | 13.50-24 | 82.5
12000 | —— | 90.0
ASSUMED VALUE FOR k=2.0 (FORMULA 4)
12,000
8000
4000
SUBGRADE SUPPORTING VALUE - POUNDS PER SQUARE INCH
THICKNESS - INCHES

FIGURE 7

CALCULATED THICKNESS REQUIRED FOR TRUCK WHEEL LOADS ON SINGLE TIRES

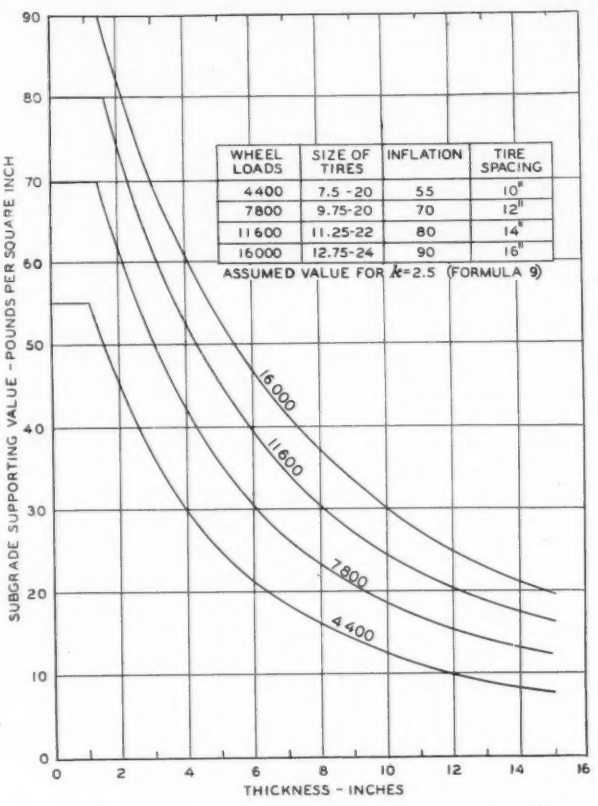
WHEEL LOADS | SIZE OF TIRES | INFLATION | TIRE SPACING
4400 | 7.5-20 | 55 | 10"
7800 | 9.75-20 | 70 | 12"
11600 | 11.25-22 | 80 | 14"
16000 | 12.75-24 | 90 | 16"
ASSUMED VALUE FOR k=2.5 (FORMULA 9)
16,000
11600
7800
4400
SUBGRADE SUPPORTING VALUE - POUNDS PER SQUARE INCH
THICKNESS - INCHES

FIGURE 8

CALCULATED THICKNESS REQUIRED FOR TRUCK WHEEL LOADS ON DUAL TIRES

TABLE II

SERVICE LOAD AND INFLATION TABLE FOR TRUCK AND BUS BALLOON TIRES BASED ON TIRE AND RIM ASSOCIATION STANDARD, TABLE TB-2

TIRE SIZE	LOADS AT VARIOUS INFLATION PRESSURES											
	40	45	50	55	60	65	70	75	80	85	90	95
5.50–20		1225										
6.00–20		1400										
6.50–18			1550									
7.00–18				1800								
7.50–20				2200								
8.25–22					2850							
9.00–20						3250						
9.75–20							3900					
10.50–22								5000				
11.25–22									5800			
12.00–24										6950		
12.75–24											8000	
13.50–24												9100

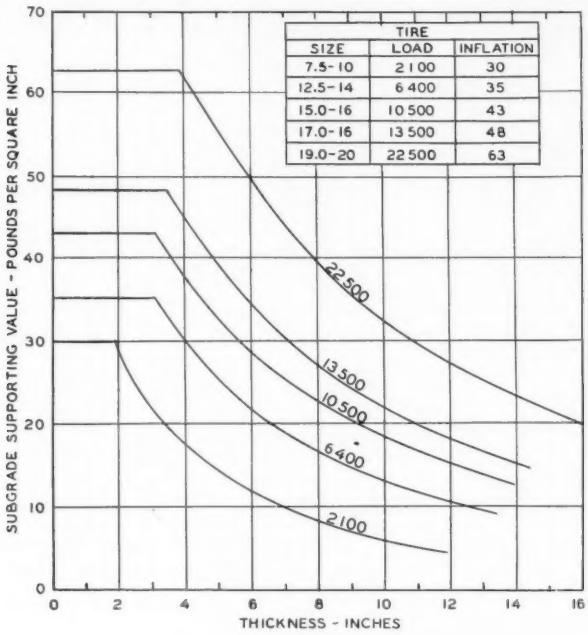

FIGURE 9

CALCULATED THICKNESS REQUIRED FOR AIRPORT RUNWAYS

TABLE III

Truck and Bus Tires and Dual Spacings	
Tire Size Nominal Cross-Section	Dual Spacing Center to Center
BALLOON TIRES	
5.50	7¼"
6.00	7¾"
6.50	8¼"
7.00	9"
7.50	10"
8.25	10½"
9.00	11½"
9.75	12"
9.75	12¾"
10.50	13¼"
11.25	14"
12.00	15¼"
12.75	16"
13.50	16"
HIGH PRESSURE TIRES	
5"	7¾"
6"	9"
7"	10"
8"	11½"
9"	12¾"
10"	12¾"

In conclusion, let it again be stated that the present method of design is tentative and will need correction as better information becomes available. Admittedly somewhat crude and not wholly scientific, still it compares not unfavorably in that respect with other so-called rational design theories which are found useful to engineers. A truly rational theory for non-rigid road design may never be entirely possible and even if attained would still involve many variables which would have to be evaluated for each application. At best, the non-rigid road, and to an almost equal extent the rigid road surface as well, involve uncertainties in their design, but the method now suggested, at least is founded on subgrade pressure tests and gives an approximation to the truth. For these reasons its publication seems to be justified.

Accidents— Your Personal Problem[1]

ACCIDENTS touched the life, or the pocket book, of one out of four Americans in 1939.

Accidental death overtook 93,000. The lives of hundreds of thousands were thus saddened.

Accidental injury, ranging from a day's disability to permanent and complete crippling, struck 8,800,000 men, women and children. These injuries reflected sorrow and financial loss on perhaps twice that number of other persons.

Property damage due to accidents totalled over a billion dollars. Almost ten million automobile drivers damaged their own cars or those of others.

Half a million drivers were involved in accidents which brought death or injury to others.

Hundreds of thousands of homes were disrupted by fire, losses ranging from temporary inconvenience to complete destruction of the home and personal property, with injury or death often contributing suffering and distress.

Direct and indirect losses to the nation's industry approached a billion dollars. Millions of workers, owners and shareholders with varying stakes in the nation's business helped pay the bill.

Last year's accidents were a source of sadness and suffering to a large proportion of our people and were a serious tax on our national resources.

Unquestionably—accidents are your personal problem!

[1] Accident Facts, 1940 Edition.

Crushed and Broken Stone in 1939

By OLIVER BOWLES and M. S. JENSEN

Nonmetal Economics Division,
U. S. Bureau of Mines

THE total output of crushed and broken stone in the United States in 1939, as reported to the Bureau of Mines, United States Department of the Interior, by producers, amounted to 145,148,770 short tons valued at $132,908,489, an increase of 18 per cent in quantity and 13 per cent in value compared with 1938. Included in this total is stone sold or used for concrete aggregates, railroad ballast, riprap, agricultural limestone, refractory stone, stone for metallurgical use (flux), limestone sand, alkali works, calcium carbide works, sugar and glass factories, paper mills, and various other chemical and manufacturing processes. Stone used in the manufacture of lime or cement, asphaltic stone, and slate used for granules or flour are not included in this total.

Crushed or broken stone used for concrete aggregates and railroad ballast constituted 72 per cent of the industry in 1939—103,891,020 short tons valued at $93,958,275. Nearly 46 per cent of the concrete and road making aggregates was produced by noncommercial operators (States, counties, municipalities, and other government agencies). Noncommercial production in 1939 increased 29 per cent compared with 1938, whereas commercial output declined 1 per cent.

In 1939 64 per cent of the commercial aggregates was transported by truck; 22 per cent by railroad; 9 per cent by water; and the remainder unspecified. Comparable figures for 1938 are as follows: Truck, 60 per cent; rail, 22 per cent; waterway, 10 per cent.

Crushed stone for metallurgical purposes, which ranks next to concrete aggregates in quantity consumed, increased 78 per cent in quantity and 82 per cent in value. Limestone for agricultural use (5,459,260 short tons valued at $6,592,827) increased in both quantity and value. Of the total, 487,500 short tons valued at $513,508 was noncommercial production by the Soil Conservation Service, W.P.A.,

CRUSHED AND BROKEN STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1938-39, BY PRINCIPAL USES

Use	1938			1939		
	Short tons	Value		Short tons	Value	
		Total	Average		Total	Average
Concrete and road metal	88,787,080	$84,212,446	$0.95	96,894,220	$88,988,217	$0.92
Railroad ballast	5,975,970	4,554,775	.76	6,996,800	4,970,058	.71
Metallurgical	9,702,860	6,943,429	.72	17,287,790	12,632,243	.73
Alkali works	3,634,050	1,743,173	.48	4,655,960	2,100,535	.45
Riprap	6,210,520	6,995,418	1.13	5,811,740	5,851,732	1.01
Agricultural	4,367,410	5,637,485	1.29	5,459,260	6,592,827	1.21
Refractory (ganister, mica schist, dolomite, soapstone)	659,690	991,765	1.50	1,492,310	2,044,054	1.37
Asphalt filler	288,590	789,587	2.74	265,710	676,978	2.55
Calcium carbide works	246,010	137,522	.56	274,890	233,085	.85
Sugar factories	619,910	878,028	1.42	621,730	853,235	1.37
Glass factories	170,560	290,297	1.70	240,840	394,727	1.64
Paper mills	223,450	373,207	1.67	302,620	488,079	1.61
Other uses	2,186,720	3,929,752	1.80	4,844,900	7,082,719	1.46
	123,072,820	117,476,884	.95	145,148,770	132,908,489	.92
Portland cement (including "cement rock") [1] / Natural cement ("cement rock") [1]	26,183,000	[2]	——	30,463,000	[2]	——
Lime [3]	6,694,000	[2]	——	8,509,000	[2]	——
Total stone	155,950,000	——	——	184,121,000	——	——
Asphaltic stone	[4] 449,091	[4] 2,219,159	4.94	422,484	2,007,810	4.75
Slate granules and flour	349,000	2,489,962	7.14	351,780	2,581,089	7.34

[1] Value reported as cement in the chapter on Cement.
[2] No value available for stone used in manufacture of cement and lime.
[3] Value reported as lime in chapter on Lime.
[4] Revised.

CRUSHED STONE SOLD OR USED BY COMMERCIAL AND NONCOMMERCIAL[1] OPERATORS IN THE UNITED STATES, 1935-39[2]

Year	Commercial operations			Noncommercial operations			Total
	Short tons	Average value per ton	Percent of total quantity	Short tons	Average value per ton	Percent of total quantity	Short tons
1935	38,090,660	$.90	69.6	16,663,860	$.87	30.4	54,754,520
1936	57,494,430	.93	65.9	29,776,390	.95	34.1	87,270,820
1937	62,315,350	.88	70.5	26,117,220	1.06	29.5	88,432,570
1938	60,254,170	.88	63.6	34,508,880	1.04	36.4	94,763,050
1939	59,516,270	.86	57.3	44,374,750	.97	42.7	103,891,020

[1] By States, Counties, Municipalities, and other Government agencies, directly or under lease.
[2] Includes stone for concrete and road metal and railroad ballast.

and other governmental agencies. Refractory stone (ganister, mica schist, dolomite, and soapstone) amounting to 1,492,310 short tons valued at $2,044,054, more than doubled the 1938 production (659,690 short tons valued at $991,765).

Limestone used for miscellaneous purposes increased along all lines with the exception of fertilizer filler and filter beds, which registered small declines. Limestone sand, which is comparatively new, showed an increase of 18 per cent in quantity in 1939 over the 1938 production.

The accompanying tables present the salient statistics of the crushed and broken stone industries in 1939.

CRUSHED OR GROUND LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES FOR MISCELLANEOUS USES, 1939

Use	1939	
	Short tons	Value
Alkali works	4,655,960	$2,100,535
Calcium carbide works	274,890	233,085
Coal-mine dusting	68,260	180,123
Filler (not whiting substitute):		
Asphalt	265,710	676,978
Fertilizer	116,080	185,844
Other	84,910	330,359
Filter beds	105,850	81,277
Glass factories	240,840	394,727
Limestone sand	270,430	183,035
Magnesia works (dolomite)	89,390	147,129
Mineral food	68,580	267,269
Mineral (rock) wool	123,720	102,670
Paper mills	302,620	488,079
Poultry grit	39,010	180,529
Refractory (dead-burned dolomite)	824,930	713,991
Road base	524,240	445,040
Stucco, terrazzo, and artificial stone	33,820	179,321
Sugar factories	621,730	853,235
Whiting substitute[1]	175,460	948,528
Other uses[2]	183,400	225,636
Use unspecified	52,990	80,403
	9,122,820	$8,997,793

[1] Includes stone for filler for graphite, calcimine, linoleum, paint, pigments, pottery, putty, regrinding, rubber, sealing wax, soap, tile, and uses not specified.
[2] Includes stone for acetic acid, acid neutralization, bird gravel, cement blocks, chemicals (unspecified), concrete blocks and pipes, dye works, explosives, fill, fireplace stone, foundry facings, lime burning, roofing gravel, spalls, and waste rock.

Detailed County Maps Available

A NEW kind of county map, showing all highways and all structures in rural areas, will soon be available through State highway departments, it was recently announced by the Public Roads Administration of the Federal Works Agency. Drafting work on sheets covering 2,741 counties—or approximately 90 per cent of the counties in the United States—has been completed.

The county maps are the result of highway planning surveys conducted by the State highway departments in cooperation with the Public Roads Administration. According to the Public Roads Administration, such maps will soon be completed for all counties in every State and many of the State highway departments already have them available for general use.

Their details range from the railroads, highways, roads and bridges to the separate dwellings, farm units and stores and industrial plants in the rural areas. Distinction is made between occupied and vacant structures. Streams actually navigable are shown. Also shown are such details as schools, hospitals, churches, cemeteries, camps or lodges, oil and gas wells, mines and quarries, power plants, radio stations and air fields.

The Public Roads Administration and the State highway departments are making special efforts to keep these maps annually revised and up to date. Since the maps for the entire country show more than 3,000,000 miles of road, and since improvements are made annually on as many as 50,000 miles of road, the revision necessary to keep the maps abreast of road improvements completed is not a simple task.

The States are being urged to issue revised editions of the maps as frequently as important changes require.

An American Primer[1]

By PHILIP D. REED

Chairman of the Board of Directors of the General Electric Company

• What are the rules for living the American Way? Mr. Reed, in the following article, gives us his conception of this highly important subject and the reasons for his beliefs.

AS ONE who knows but little about the art of selling or the science, if it be one, of salesmanship, I was very hesitant to accept your Chairman's invitation to speak to you on any subject germane to that great field. While there are common denominators for everything, and no doubt I could discuss a few fundamental rules which all of you, whatever products or services it is your job to sell, would accept as axiomatic, I would thereby neither enlighten nor entertain you, but would be guilty of the all too common practice of talking without saying anything.

So I am going to assume that the composite, the collective knowledge and experience of you members and guests of the Sales Executives Club on the subject of sales and sales promotion are equal to and perhaps greater than that of any similar group in the world. And on that assumption, or shall I say on the basis of that obvious truth, I am going to talk to you for a few minutes and pose for your consideration a sales problem that is, or should be, a challenge to every sales executive in America, a challenge that must be met if we are to continue our system of competitive free enterprise under which the arts of sales promotion and advertising have grown and flourished so enormously.

Need I say that the job I refer to is that of selling the American way of life to Americans? It may seem paradoxical that this should be necessary or that we as a people should be considering even for a moment any other way of life. But the stark truth is that we are doing precisely that. And we are doing it because our fellow-citizens have not been told enough about or sold sufficiently upon our own American product. That, gentlemen, is where you come in—where you who are trained in the art of telling the truthful story of good products can be of immeasurable value in seeing to it that when the great question must finally be decided, it will be dealt with by an awake and understanding people.

The Important Job Ahead

What the future holds for us no one can accurately foretell. But it requires no clairvoyance to see that the next five years will in all likelihood be the most vitally important ones in the history of our nation. The things to be done during that period, the legislation to be adopted, the leadership to be developed, the reaction and response of the American people to the events which lie ahead in the struggle between dictatorship and democracy will in my judgment irrevocably fashion the pattern of life to which we, our children, and our children's children will of necessity conform.

The interest, importance, and value, therefore, during the years immediately ahead, of men and women who know and understand the methods and techniques of education, of advertising and of sales promotion, cannot be over-estimated. It follows that those trained in these arts must not only make their influence felt during these formative years, but that they must base their judgments and their action upon a real understanding of the issues, the trends and the problems with which we as a nation are confronted.

Today we are in the first throes of organizing an enormous program of national defense. No one, I think, will doubt this country's need of greatly enlarged military, naval and air defenses. To accomplish this herculean task quickly, efficiently and well, there must be the closest kind of co-operation and teamwork between government, industrial management, and labor. It is inconceivable that there should be a lack of it from any quarter, for the ultimate purpose and objective of this program is the preservation of our homes, our institutions and our way of life. Patience and understanding will be needed. Delays and disappointments will occur. Sacrifices and concessions will be required. But as Americans all—and always—with the vitality and resourcefulness and organizational ability that have enabled us to create the greatest and most efficient production machine in history, we will do this job and we will do it well.

[1] An address before the Sales Executives Club of New York, July 2, 1940.

National Problems Transcendent

Last week the Republican Party chose its candidates for high office. A fortnight hence the Democratic Party will do the same and the campaigns will then get under way. The responsibility that falls upon the delegates charged with the duty of selecting the Presidential and Vice Presidential candidates in this period of world crisis is exceeded only by that which must rest upon the shoulders of the men selected. Whatever our political preferments, I venture to say that the events of last week were gratifying to all who believe that the effective functioning of our American democracy requires not one but two strong parties, each under active, intelligent and vigorous leadership.

The great issues today are not those we are accustomed to associate with party politics. They are cosmic questions, affecting on the one hand our relationships and ability to live with the other peoples of the world, and on the other hand the review and redetermination of our own doctrines of self-government. As normal human beings we all want to find the right answers to these vitally important questions. There can be no doubt of the sincerity and loyalty of our political, industrial, and labor leaders. But they and all of us must recognize before it is too late that the problems before us are far larger than the individual interests of any party, section or group.

Large portions of the world's population have in recent years surrendered democratic freedom for dictatorship. The state has replaced the individual. These changes abroad have evidenced themselves in this country in many small ways. Each step is comparatively insignificant when taken by itself, but in the aggregate they constitute a definite and unmistakable trend toward centralization and enlargement of government powers and toward government by men rather than by laws.

Recent Gains and Losses

We have been through ten years of serious economic disorder. During that period we have made progress in certain directions, but none at all in others. For example, no one can question the fact that very real social progress has been made. The value and desirability of these accomplishments from the social standpoint are self-evident. Nor would any of us wish to see them lost, if we as a nation can support and justify their continuation. The difficulty is that social legislation almost invariably costs money, large sums of money, and can be supported only if the economic condition of the country is healthy and prosperous. We all agree, I am sure, that American citizens should not be permitted to starve, that made work is better than the dole, that old age and unemployment insurance, and guaranteed bank deposits are fine and worthy things, that maximum hours and minimum wages are all to the good in sweatshop industries, that reclamation and rehabilitation of the soil is essential for the future of America, that slum clearance and low-cost housing are much to be desired. But I repeat that these enactments cost money, billions in the aggregate, and they can be supported through the years only if our economic system is sound and successful.

The fact is, however, that the economic record of the past decade is just as disappointing as the social record is gratifying. In a recent editorial *Fortune* magazine points out that our national income is back to 1919, our unemployment problem completely unsolved, our national debt up 19 billions (now amounting to $1,250 per family) and that comparing the period 1933-39 with 1923-29, the only significant increases among twenty-two basic economic measurements were in population, strikes, strikers, Federal taxes, Federal expenditures and national debt. All the other items show a decline varying from 9 per cent to 84 per cent and include manufacturing employment, industrial production, wholesale prices, factory payrolls, national income, new construction and corporate financing.

We must, I submit, place more emphasis on economic recovery, lest, failing to achieve it, we are forced to abandon—as we surely would be—the social advances of the last decade. For government can not create wealth. All it can do is redistribute existing wealth. A great deal of new wealth must be created to support our social program, and this can be done only by increasing output, the production of useful goods. To reach this goal we must move forward on the economic front.

Security an Illusion

Oliver Wendell Holmes once said, "The longing for certainty and repose is in every human mind. But certainty is generally illusion and repose is not the destiny of man." I do not know the circumstances which prompted Holmes to make that state-

ment, but if it was true then, how deeply, how desperately true it is today. Certainty—that is to say, assured security—is generally illusion, and repose—that is to say, escape from hard work—is not the destiny of man. That quotation, gentlemen, is heavy with truth. May we all heed and profit by it.

The question of what is wrong with America's economic system, what has caused the long-continued apathy in our industrial and financial mechanisms, has produced a long list of conflicting explanations and as many suggestions, equally conflicting, for the correction of the difficulty. Stemming from totally different concepts of the cause of our lagging activity, the proposed corrective measures are not only diverse and inconsistent, but certain of them would alter fundamentally our traditional view of government and its functions and the jealously guarded freedom of action which American citizens have so long enjoyed.

Problems in a Democracy

This brings us face to face with a serious problem —a problem that is real because it goes to the roots of our system of constitutional democracy, a problem that cannot be ignored. Let us examine ourselves as adult Americans. Are we good judges, competent critics, and intelligent readers of our country's history? Are we well enough grounded in political economy to judge what is good for our future, and what is bad? Do we understand the fundamentals of the American system under which we have grown up? Lacking that knowledge of fundamentals, how can we distinguish between proposals which are consistent with the pattern of that system, and those which would impair or destroy it? Can we fashion for ourselves some kind of simple projector by which the trends and tendencies of the day can be clearly viewed and contrasted with the doctrines upon which this nation was founded? These questions, gentlemen, are far easier to ask than to answer.

We are told that the average American has received no more than a seventh-grade schooling. It is clear, therefore, that the ordinary citizen cannot be expected to understand and pass intelligent judgment upon the complex questions which are ever before us in business, banking, agriculture, government and many other fields. But it is he, nevertheless, who will determine whether and to what extent America will continue to live by the principles so firmly established by our forefathers. What can we do to keep these simple and fundamental doctrines ever before us?

No one knows better than I the difficulty of keeping even reasonably well-informed on the major problems of the day and the hours of reading and study it takes to satisfy not a New England but merely a Midwestern conscience that one's views and pronouncements on current questions are not simply parroted from his favorite columnist but are bottomed by thoughtful analysis and honest conviction. And because our government is and must be active in so many fields, and because the legislative and administrative questions before it are so diverse and numerous, it is most difficult to preserve perspective, to see the forest despite the trees, and to maintain an objective and consistent viewpoint. The task of thinking simply, unemotionally and directly has perhaps never been more difficult and surely never more urgently needed than in this forty-first year of the twentieth century.

Need for a Restatement of Principles

Formulae for thinking, like rules for making friends and influencing people, must be open to the charge of over-simplification and must prove to some extent ineffectual. Nevertheless, in this disturbed and complex day in which we live, when in foreign lands outlaws and iconoclasts seem successfully to be defying the validity of the virtues we have always embraced, when character and integrity appear almost to inhibit rather than to help one's cause, it may not be unprofitable for each of us to sit down quietly and restate to ourselves as simply and briefly as we can the fundamental principles which made, and if we hold firmly to them which will preserve, our American way of life.

Were we each to do this, the enumerations would doubtless differ, both in number of items and in the order of importance of the common ones. The central core, however, would surely be the same. If from that core we could formulate a simple one-page statement, a primer if you like, of the doctrines of American self-government, and if we could spread that statement far and wide across the land for every American to read and live by, the present trends toward government by men rather than by laws, toward enlargement and centralization of government functions and toward government by small

but articulate pressure groups, would be arrested in their tracks.

Primer of Self-Government

And were I asked to set down in brief and simple fashion the items I would include in a Primer of American Self-Government, they would be these seven:

Our American Constitution is of inestimable value. In clear language it safeguards the fundamental rights of the individual. It limits the powers of government to those expressly and by clear implication granted to it. Because amendment is difficult and time-consuming, it stands as a bulwark against hurried, ill-considered or emotional change. The first item of my Primer of American Self-Government is, therefore:

1. Understand, honor and preserve the Constitution of the United States.

American government, whether national, state or local, comprises three branches, which in order to prevent concentration of power, must always be kept separate and distinct. They are the Legislative branch, whose duty it is to enact all laws subject only to the principles and limitations laid down by the Constitution; the Executive branch, whose duty it is to administer, but never to make, the laws of the land and to operate all government services; and the Judicial branch, whose duty it is to interpret the laws made by the legislature, to decide whether they conform to the Constitution, and whether acts or omissions of the people or the other departments of government are in accordance with the law. The second item of my Primer is, therefore:

2. Keep forever separate and distinct the legislative, executive and judicial functions of government.

Government is created by and belongs to the people. It has no rights or powers except as the people grant them. The cost of government must be paid for by the people through taxation, and the tendency is for government to grow and become increasingly costly. Because government is not like private enterprise, in which competition and the profit motive provide a tremendous incentive to careful planning and efficient operation, government is inherently less efficient than private business. Therefore it should be permitted to do only those things which government alone can properly do and which are necessary for the welfare of the people. Thus the third item of my Primer becomes:

3. Remember that government belongs to the people, is inherently inefficient, and that its activities should be limited to those which government alone can perform.

Of the many rights and guarantees which Americans enjoy under the Federal and State Constitutions, perhaps the most important are freedom of speech, freedom of worship according to one's own conscience, and freedom of decision and action in such matters as where to live, what kind of work to engage in, whom to work for and at what pay. This freedom of action, coupled with the right of the American citizen to have and to hold the fruits of his labor and to save or dispose of them as he wishes, is called the Enterprise System, and it provides opportunity and incentive to improve one's position in life. Our fourth item, accordingly, is:

4. Be vigilant for freedom of speech, freedom of worship, and freedom of action.

The Enterprise System under which thousands of private businesses and millions of men and women are constantly searching for new, better and more useful products and services, and for ways to improve and lower the cost of existing ones, has produced a standard of living in this country higher than any which the world has ever known. The enterprise system cannot function successfully without incentive to improve, expand and to create new enterprises. Accordingly if the profits of business are taxed inordinately, or if restraints and limitations are imposed which deprive the managers of reasonable freedom of action, or if government competes or threatens to compete with private business, the Enterprise System will languish. These things should therefore be avoided, and if they are, the inherent incentives of the system will cause business to expand, to create new enterprises and profitably to produce ever better, ever cheaper goods for more people to buy. Along this road lies progress and the only permanent solution of our unemployment problem. The fifth item is therefore:

5. Cherish the system of Free Enterprise which made America great.

Thrift and economy are still the great virtues they were in our grandmothers' time. Debt burdens the future and too much of it impairs one's credit. Bor-

rowing, therefore, should be resorted to only in periods of real emergency. These principles apply equally to government and to private citizens. The difficulty is that government can borrow more readily than the citizen, and having borrowed for the benefit of one group, it is very difficult not to do so for other organized groups. Our national debt has risen enormously in the past ten years despite substantial increases in taxation. All this money must some day be repaid out of future taxes. Our immediate problem is to stop piling up more debt. This is not easy, indeed for the moment it is impossible. The safeguard we must seek is widespread understanding of the problem plus realistic and courageous leadership. Briefly stated, our sixth item becomes:

6. Respect thrift and economy, and beware of debt.

Integrity of contract and respect for the rights of others are foundation stones of civilization. They have been all but destroyed in many quarters of the world, and until they are restored barbarism will stalk the earth. Let us keep the candle of integrity burning brightly in America. If we do so we shall one day use it to rekindle the flame of mutual trust, fair dealing, and respect for others in a suffering and chastened world. The seventh and last item of our Primer is, therefore:

7. Above all, let us be scrupulous in keeping our word and in respecting the rights of others.

This, then, is one Primer of American Self-Government. If each of you would write your own I am sure I would be satisfied to accept them. For it seems to me that the principles are so simple, so clear, that having thought them through we may say of them in the language of our forefathers, "These truths we hold to be self-evident."

The Story Must Be Told

But thinking on these subjects, and particularly thinking through on them, is not sufficiently widespread. Is it not our task as Americans to encourage and stimulate such thinking in every way at our command? For if our educators, our business and professional men, our churchmen and our farmers, our trade and civic organizations, would write their Primers of American Self-Government and tell the story on a national scale through the press, the radio, the pulpit, the classroom and the public forum, how could we fail to reinculcate in the minds of our 130 million home-loving citizens, the rules for living the American way? It is a selling job, gentlemen—the kind of job at which you are expert.

And now in closing let me say that I have deliberately avoided anything but passing reference to the wars abroad. Tragic and disastrous as they are for those involved and for ourselves, and essential as it is for us to view them realistically and to prepare for bitter times ahead, let us emphatically remember that these wars may obscure but they cannot and will not cure our domestic ills. Indeed, if on a peacetime basis we view dangerous tendencies toward the extension and concentration of government, toward the creation of too powerful bureaucracies and toward unparalleled enlargement of our national debt, is it not clear that the preparation for or actual engagement in war must speed and aggravate these tendencies? Let us, therefore, keep our vision unclouded by emotionalism, and let us recognize that conditions beyond our borders make ever more compelling the need for understanding, for teaching and for living our Primer of American Self-Government.

Highway Research Board Meets December 4-6, 1940

THE Twentieth Annual Meeting of the Highway Research Board of the National Research Council will be held in Washington at the building of the National Academy of Sciences the week beginning December 2.

Sessions of the Board will be held on Wednesday, Thursday and Friday, December 4 to 6. In addition, several Departments of the Board will hold open meetings on Tuesday, December 3.

According to the tentative schedule released by Roy W. Crum, Director of the Board, the Departments of Design, Materials and Construction, Maintenance, Economics and Soils and the Committee on Roadside Development have scheduled meetings on Tuesday, December 3 which will be open to the public.

Board sessions will start Wednesday morning, December 4 with the discussions centered about materials and soils investigations. On Wednesday afternoon will come topics relating to highway economics; Thursday morning, traffic; Thursday afternoon, design and roadside development; Friday morning, finance and maintenance.

Transportation—Its Use and Misuse in Peace and War*

By M. J. GORMLEY

Executive Assistant,
Association of American Railroads

• The crushed stone industry will recall with real concern car shortage difficulties of the last war and will properly wonder if similar difficulties are to be anticipated in the current emergency. Mr. Gormley believes not, and for reasons set forth in the following article.

IN A world at war, we are being constantly reminded that transportation is a vitally important factor in the conduct of offensive or defensive military operations. Therefore, the problem of the use and misuse of transportation in peace and war is extremely important to the general public as well as to the War and Navy Departments. Any approach to this problem should take into consideration what happened before and after the entry of this country into the last war.

Freight Traffic Situation in War Period

Congestion of freight traffic in 1917 and 1918 was due to the shipment of materials and supplies far beyond the ability of the receivers to absorb, the loading of cars with vast exports without consideration of the availability of ocean shipping, and the legal requirement that government freight be given preference and priority in movement without any consideration being given to the ability to unload promptly. At one time, something over 200,000 cars were under load and standing still and could not be moved for the reason that there was no place to unload them. The seriousness of that situation is best appreciated when we consider that tying up over 200,000 cars reduced the transportation capacity by approximately 20 to 25 per cent.

At that time there was lack of co-ordination of purchase and procurement of supplies and in arranging for transportation in the War and Navy Departments, with indiscriminate issuance of priorities and consequent confusion which interfered with the proper movement of freight caused by cars being used for storage purposes and no arrangements being made for their prompt unloading. The big lesson that we learned from that experience was that the transportation plant should always be considered and used as an instrument of mobility and not as a storage facility.

With respect to the lessons learned as a result of wartime transportation experience, the report of the Director General of Railroads for the year 1918 has this to say:

> The controlling factor throughout our experience has not been in the road transportation, but at the ultimate destination, and any serious conditions of congestion obtaining on any of the trunk lines en route has been the reflex of conditions at the terminals themselves.
>
> Practically all transportation in the United States has been based primarily upon the desires and necessities of the consignor rather than upon the abilities of the consignee to receive and digest the freight.

That this is thoroughly understood by the War and Navy Departments is evident by the plans adopted by the Army and Navy Munitions Board, which provide that material must not be loaded on cars unless it is known at the loading point that such cars can be unloaded promptly on arrival at destination.

A great many strange things happened at that time but I recall one that is typical of the hysteria that prevailed and which is likely to develop at any time unless proper methods of control in the use of transportation are exercised. The instance I have in mind was the construction of the Hog Island Shipyard. I have made reference to this many times in addressing Army officers and it is an old story but, nevertheless, it is typical of what can happen when the use of transportation is not properly controlled.

When it was determined that the Hog Island Shipyard would be constructed, the principal concern seemed to be that of transportation, the statement being made that if they could only get transportation there would be no delay in the construction work. Piling was one of the important materials needed for the work. Orders were immediately

*Address delivered at the Annual Meeting of The Society of American Military Engineers on May 6, 1940.

placed, and cars for loading were promptly made available. In this connection the report of the Director General, above referred to, said:

> Heavy building operations by different branches of the Government, the contractors for which ordered materials forwarded far in advance of their ability to receive and unload. There was at one time over 5,000 carloads of piling alone for the Hog Island Shipyard in excess of its ability to accept.

They also had on hand cars loaded with anchors for ships before the keel was even laid for the first boat. Occurrences of this kind could be multiplied many times. They did not realize then that obtaining transportation was the least of their problems.

The railroads, the public generally, and the War and Navy Departments not having had experience of this kind prior to the war, it was not surprising that many mistakes were made in the handling of transportation. Unless we learn from this experience how to avoid possibility of similar occurrences in another war, then the experience gained during that time will be of no value.

Attempt to Co-ordinate Transportation

At the Union Station, Washington, D. C., on April 26, 1940, there was dedicated a bronze plaque to the patriotic services of American railroads in voluntarily forming a board in 1917 to co-ordinate rail transportation facilities to meet wartime needs.

The records show that on April 11, 1917, five days after war was declared, Mr. Daniel Willard, Chairman, Advisory Commission of the Council of National Defense, called a meeting of fifty executives of the nation's principal railroads, pointed out to them the importance of transportation in connection with the war operations and, to meet those needs, indicated that the railroads would have to operate as one vast system. Accordingly, such an arrangement was made and the railroads pledged co-ordination of their operations during the war in a continental railway system, and merged during such period all their individual and competitive activities in an effort to produce a maximum of national transportation efficiency.

As a result of the planning of improvements in operation and a spirit of co-operation, a remarkable transportation performance was established. During the first eight months of the war more than 2,000,000 troops were moved between military posts and to mobilization points, cantonments, the Mexican border and the Atlantic ports. In addition, the railroads carried more freight and passengers in 1917 than in any previous year.

However, congestion of freight traffic and many long delays in unloading cars eventually created a car shortage which was due only to cars being held for discharge of cargo, and this, I think, more than anything else forced the government to take over the railroads.

The Railroad War Board remained on duty until December 28, 1917, when the government took over the railroads.

Railroads Now Organized to Meet Any Traffic Demands

It will be noted from this that it was necessary at that time to create an emergency railroad organization. However, that condition does not exist today. The railroads are now thoroughly organized, through the Association of American Railroads, immediately to meet any demands of commercial or war traffic that may be required, and no other central organization is needed.

The Association is composed of all the essential trunk lines and most of the essential short lines. Its headquarters are in Washington. The President of the Association is assisted by an Executive Committee of six railroad chief executives, selected from different parts of the country. The By-Laws provide that when necessary this Executive Committee would be in continuous session.

Without question, the Association now has all of the authority required to meet any predictable situation but, certainly, if it is determined that the authority is not as complete as it should be, the railroads can be counted upon to give this organization such additional authority and support as is necessary.

To eliminate the possibility of traffic congestion again occurring, the Association of American Railroads has an embargo and permit system under which it can prevent the accumulation of loaded cars beyond the ability of receivers to unload promptly. This plan has been in effect for a number of years and is frequently used. As is well known, an embargo is a method of controlling traffic movements when accumulations, threatened congestions or other interferences with operation, of a temporary nature, compel restrictions against such movements.

So far as the strictly commercial traffic is concerned, that will be controlled by the railroads through this Association to prevent congestion. If any industry has more cars arriving for it than can be promptly unloaded, such industry will be embargoed and no permits will be issued until it can demonstrate that the traffic can be promptly unloaded. While, as stated, the railroads have no such jurisdiction over the shipment of war materials and supplies, at the same time that situation is controllable by the War and Navy Departments in accordance with their present plans as heretofore stated. This plan is a recognition of the very important objective of preventing the use of transportation facilities for storage purposes.

Receivers of freight can by a close check on their own business avoid the necessity for the railroads making this embargo and permit plan fully effective by not ordering materials beyond their capacity to unload promptly. Of course, this is the most desirable method of control. The receivers can be certain that the railroads will avoid any unnecessary restrictions or annoyances in the normal movement of traffic and will only use this method of control when necessary to prevent the use of cars for storage purposes to the dertiment of all interests.

Port Traffic Control Plan

The ability to avoid congestion of traffic through proper control is demonstrated by the situation presently existing in the various Atlantic and Gulf ports. Under date of November 7, 1939, the railroads installed a system of port control to avoid congestion, with a Manager of Port Traffic, located at New York, of the Car Service Division, Association of American Railroads.

This plan provides that if and when control is considered necessary at any one of the Atlantic ports, it will be made to cover all ports, each to the extent deemed necessary, since conditions which make for congestion at any one of them will quickly affect them all. The control system will cover all roads serving a port. It will cover all traffic for, or intended for, export, except as specifically exempted. If necessary it will be extended to cover traffic for coastwise or inter-coastal movement and domestic freight for the port or ports affected. If and when conditions make it seem desirable that the movement of traffic be controlled at ports other than the North Atlantic ports, such situations will be covered by separate instructions, under the direction of the Association of American Railroads, as occasion may require.

It is of interest to know how that plan is working out. I believe this is easily demonstrated by the situation existing particularly at the North Atlantic ports in February of this year compared with the same month in 1918. There were exported through the ports 664,000 tons in February, 1918, and 693,000 tons in February, 1940. In 1918 there was congestion at the ports, embargoes were in effect and permits were outstanding for 16,798 cars. In 1940, with a greater traffic, there was no congestion or delay of any kind.

This is truly a great record and is due to the most excellent co-operation of all interested with the Manager of Port Traffic located at New York. It is an excellent example of preparedness and supports the conviction that, regardless of the volume of traffic available for these ports in the future, it can be handled in the same satisfactory manner as at present.

The Problem

Before one can reach the solution of a problem he must have as clear an understanding as possible of what the problem really is; that is, what is likely to be the demand for transportation during the period of a war. I have often attempted to get some definite information on this subject from the War Department but without success, as apparently there are no available statistics that will give that information. Therefore, we arrived at the conclusion that the war load in the last war would be equal to the total increase in traffic from the year 1916, when we were not in the war, to 1918, when we were in the war. After doing this, we found this increase was only about 12 per cent of the total commercial load. This 12 per cent is not as much of an increase in traffic as the railroads experience from one season of the year to another or from one year to another in the handling of ordinary commercial traffic, and it does not present a problem of any magnitude, providing the movement of such traffic is under proper control to prevent the use of cars for storage purposes.

Under the Railroad War Board was established the plan of organization for the movement of troops. This plan was carried out with entire satisfaction to all interested and was continued by the government after taking over the railroads. The organization, in skeleton form, is still in existence, established at the War Department for dealing with the ordinary

peacetime requirements of that Department and can readily be expanded.

The troop transportation from May, 1917, to December 31, 1919, involved the movement of a total of 15,756,981 men. The average movement was 492,405 per month. The monthly maximum was reached in July, 1918, when 1,147,013 men were moved. There were 25,953 special trains and the monthly maximum was 2,055 trains in July, 1918, with 759 miles traveled per train. While this may appear to be a very heavy troop movement, as a matter of fact it was only 6 per cent of the total passenger movement that took place during this same period.

Transportation Program in 1923

The railroad machine today is a totally different one than existed during the last war. The railroads were returned to their owners in 1920 with a machine that had deteriorated during the twenty-six months of government control. Almost immediately thereafter the railroads were confronted with strikes and greatly unsettled conditions. There followed what was then known as a year of depression, in 1921, with more strikes in the railroad field in 1922. The first year of fairly normal conditions was in 1923. Early in that year a careful survey indicated that before many months the railroads would be called upon to handle the greatest volume of traffic in their history.

Fully realizing this, the railroads adopted a joint program of rehabilitation and modernization of the plant and equipment to enable them to provide adequate service with the greatest possible efficiency. Standards of efficiency and goals of achievement were set up with a view to handling satisfactorily the anticipated increase in traffic. This program involved large expenditures for equipment and other facilities. It also called for greater co-operation than ever before among the railroads and between the railroads and shippers. One of the results of this co-operative program was the organization of thirteen shippers' regional advisory boards. The purposes of these boards were:

> To form a common meeting ground between shippers and railroads for the better understanding of transportation questions, to adjust informally car service difficulties which may arise between carrier and shipper and to give the shipping public a direct voice in the activities of the Car Service Division (Association of American Railroads) on all matters of mutual concern.

All of the objectives of this program were fully realized.

Increase in Rail Efficiency

New equipment was installed; much of the older equipment was rebuilt and repaired. Since that time there have been no car shortages, the speed of freight trains has been increased over 60 per cent, average capacity of freight cars has increased approximately 20 per cent and number of gross ton miles per train hour have more than doubled. More than 1,768,000 freight cars and 40,000 locomotives have been destroyed as obsolete. The number of freight cars owned is now approximately 724,000 less and locomotives owned approximately 24,000 less than at the high points of ownership.

Improvements in speed of movement and efficiency have been so great during this period that the freight traffic in 1929, the greatest for any year on record, could now be handled with from 350,000 to 400,000 fewer cars than were required at that time. It is evident, therefore, that any comparison of the capacity of the railroads today with any previous period, based only on units of equipment owned, means absolutely nothing—the greatly increased efficiency must be taken into consideration.

This is clearly demonstrated by a comparison of the figures of 1929 with the war year of 1918. There were loaded in 1929 over 8,000,000 more cars of freight than were loaded in 1918, with approximately 60,000 less cars and 5,000 fewer steam locomotives than were owned in 1918.

Last fall there seemed to be great concern on the part of some people as to whether the railroads would be able to handle a greatly increased traffic. Cars loaded for one week in the middle of May, 1939, totalled 555,396; cars loaded at the peak week in October were 861,198. This was an increase of 305,802 cars, or 55 per cent, the heaviest increase that ever occurred in traffic on the railroads in such a short period of time. This is a further demonstration of the fact that the railroads are always in a state of national defense. If they were not, they could not properly handle the commercial traffic with such great fluctuations as this statement indicates. This peak traffic was handled without difficulty, without car shortages and without delay in unloading at destination. This performance required

and received shipper and receiver co-operation in every direction.

If, in the event of another war, we could avoid the hysteria and retain the proper perspective with respect to the volume of the war load and not interfere with the normal methods of movement, no difficulty whatever would be encountered in providing adequate and satisfactory service.

This was amply testified to by the Assistant Secretary of War Louis Johnson, in a statement he made at the dedication of the War Board plaque, heretofore referred to, at Union Station on April 26, when he said that the rail carriers "have proven their ability and their capacity" and now are better prepared to meet a military emergency than they were in 1917. The government, he revealed, "is satisfied that the railroads under private management are always in a state of national defense."

Motorists Now Help Design Highways[1]

IF WHILE driving along the highway you cross a series of slender black strips laid across the pavement, you then and there do your part towards designing the highways of tomorrow.

Adopting the fundamental principle that the road must fit the traffic, rather than the other way around, highway engineers have enlisted the unconscious cooperation of hundreds of thousands of motorists from Massachusetts to Oregon to record exactly what most drivers make their cars do under any given set of conditions.

Millions of little pen scratches, electrically operated by cars crossing those pavement strips, translate into a complete story of car speed, passing habits and road "hogging" if any, of a normal number of people under a variety of conditions.

Width of pavement, sight distances, degrees of road curve, all are to be predetermined for the future on the basis of what drivers' conduct shows they need.

In order to get accurate information on what takes place in a moving stream of traffic, local and federal officials have developed new checking devices which tell more about how motorists drive their cars than the drivers know about themselves.

In overtaking and passing a car ahead, for instance, the average driver looks for a reasonable length of space for the operation, but does he know just how much space he actually utilizes at a given speed?

When a car approaches from the opposite direction, the average driver tends to pull over slightly to the edge of his traffic lane—but how much?

When taking curves, some drivers hug the inner edge, and some swing fairly wide—but again how much, and how many perform one operation and how many the other?

These are the questions highway engineers want answered on a large enough scale to take into account a wide variety of road conditions, geographically distributed to include major differences in driving habits.

When the Public Roads Administration, in collaboration with state highway officials launched their nation-wide survey of the country's highway needs, an important feature was to set up equipment for checking the volume and behavior of traffic. Special devices were designed for use on existing highways and sample surveys have been conducted in a number of states. Unconscious that his car was breaking the beam of an electric eye or recording its progress on electrical tape laid across the road, many a motorist has left a record of his speed, direction and driving practices in light and heavy traffic.

Here are some findings from studies made in Maryland and Virginia:

More than four-fifths of all drivers going around slower cars desired to travel less than 16 miles per hour faster than the cars they passed. More than half desired to travel less than 11 m. p. h. faster.

Of all the drivers passing single vehicles, 84 per cent had to slow down before they could start to pass. About one-third had to slow down and stay behind the preceding car until they could see that the road was clear for a sufficient distance ahead to permit them to pass. Slightly more than half had to slow down and wait for an on-coming vehicle to pass before they could start the passing maneuver.

In more than 50 per cent of the passings recorded, the passed vehicle was travelling from 31 to 40 m. p. h.

Incidentally, in one set of studies it was found a surprisingly large number of drivers did not attempt to pass a car ahead when the sight distance was longest, but waited until their view ahead was reduced. Such data is excellent for studying the average driver's perception of a set of conditions and the judgment time necessary to react.

[1] Reprinted from "Automobile Facts," June, 1940.

New Federal Highway Act Provides $327,000,000

THIS law is based on previous federal-aid highway legislation but includes several new innovations.

The amounts as provided for each of the fiscal years ending June 30, 1942 and June 30, 1943 are as follows:

	Fiscal years 1942-1943
Federal-aid System	$100,000,000
Secondary Roads	17,500,000
Grade Crossings	20,000,000
Forest Highways, etc.	10,000,000
Public Land Roads	1,500,000
National Park Roads	4,000,000
Parkways	7,500,000
Indian Roads	3,000,000

National Defense Provisions

The new bill authorizes the use of funds made available under Section 21 of the Federal Highway Act to pay the "entire engineering costs of surveys, plans, specifications, estimates and supervision of construction of projects for such urgent improvements of highways strategically important from the standpoint of national defense on order of the Federal Works Administrator in cooperation with the Secretary of War, the Secretary of Navy or other authorized national defense agency". Another section dealing with national defense provides "in approving federal aid highway projects to be carried out with any unobligated funds apportioned to any state, the Commissioner of Public Roads may give priority of approval to, and expedite the construction of, projects that are recommended by the appropriate federal defense agency as important to the national defense."

R. F. C. Aid For Right-of-Way

The Hayden-Cartwright Act of 1940 authorizes the Reconstruction Finance Corporation to cooperate with the states to aid in financing the acquisition of real property necessary or desirable for road projects eligible for federal aid. It is further provided that any such transaction shall be made only after approval of the project by the highway department of the state concerned and by the Public Roads Administration of the Federal Works Agency. While these provisions do not make any substantial change in the existing authority of the R. F. C. they nevertheless constitute a strong declaration of policy.

Secondary Roads

Section 17 of the Act provides for an extension of time, from June 30, 1940 to June 30, 1941, for the unexpended balance of funds for secondary roads as provided in the 1936 Federal-aid Highway Act.

Flight Strips

Section 13 authorizes the Commissioner of Public Roads, in cooperation with the State Highway Departments, upon request, to investigate the location and development of flight strips adjacent to public highways or roadside development areas, for the landing and take-off of aircraft.

Program For National Defense Highways

In cooperation with the Army and Navy Departments the Public Roads Administration is making a survey as to the needed improvements in a selected system of highways of strategic military importance. It is expected that a report will be made to the President sometime in October. The following is an outline of the program now under study.

Strategic Network		
Total mileage of network		75,000 miles
Total number of rural bridges		16,000
Number of rural bridges with capacity less than 30,000 pounds		1,800
Number of rural bridges with vertical clearance less than 12½ feet		150
Number of rural bridges with horizontal clearance less than 18 feet		1,700
Approximate mileage of road surface less than 18 feet wide		5,500
Approximate mileage of road surface to be strengthened		14,000
Access Roads		
Total mileage		3,112
Classified as follows:		
Within reservations		1,241
Outside reservations		1,871
Approximate cost of necessary improvements		$202,000,000
Classified as follows:		
1st priority	$121,000,000	
2nd priority	31,000,000	
3rd priority	50,000,000	
	$202,000,000	

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Manufacturers of Ring Crushers and Hammermills for Primary and Secondary Crushing

Atlas Powder Co.
Wilmington, Del.
Industrial Explosives and Blasting Supplies

Earle C. Bacon, Inc.
17 John St., New York City
Primary and Secondary Crushers, Rolls, Screens, Elevators, Conveyors—Complete Plants designed and equipped

Broderick & Bascom Rope Co.
4203 N. Union Blvd., St. Louis, Mo.
Wire Rope, Strand and Guard Rail, Slings both plain and Braid Wire Rope

Brooks Equipment and Mfg. Co.
408-10 Davenport Road, Knoxville, Tenn.
"Brooks Load Jugger" (Stone Hauling Equipment). DAY Jaw Type Rock Crushers. DAY Pulverizers, or "Swing Hammer" Crushers

C. G. Buchanan Crushing Machinery Division of the Birdsboro Steel Foundry and Machine Co.
90 West Street, New York City
Primary, Secondary and Finishing Crushers and Rolls

Bucyrus-Erie Co.
South Milwaukee, Wis.
Excavating, Drilling and Material Handling Equipment

The Buda Company
Harvey, Ill.
Buda-Lanova Diesel Engines, Buda Gasoline Engines, Buda Lifting Jacks from 1½ to 100 tons, Buda-Hubron Earth Drill, Buda Railway Equipment and Supplies

Cross Engineering Co.
Carbondale, Pa.
Screen Plates and Sections, Perforated Plate, for Vibrating, Rotary and Shaking Screens

Deister Machine Company
1933 East Wayne Street, Fort Wayne, Ind.
Deister Plat-O Vibrating Screen, Deister Compound Funnel Classifier

Dempster Brothers, Inc.
Box 3063, Knoxville, Tenn.
DempsteR DumpsteR

E. I. du Pont de Nemours & Co., Inc.
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Explosives and Blasting Accessories

Easton Car and Construction Co.
Easton, Pa.
Quarry Cars, Truck Bodies and Trailers Electric Heaters for Tar, Asphalt or Bitumen

Ensign-Bickford Co.
Simsbury, Conn.
Cordeau-Bickford Detonating Fuse and Safety Fuse

MANUFACTURERS' DIVISION of the NATIONAL CRUSHED STONE ASSOCIATION

Frog, Switch & Mfg. Co.
Carlisle, Pa.
Manganese Steel Department—Manufacturers of "Indian Brand" Manganese Steel Castings for Frogs, Switches and Crossings, Jaw and Gyratory Crushers, Cement Mill, Mining Machinery, etc., Steam Shovel Parts

General Electric Co.
1 River Road, Schenectady, N. Y.
Electric Motors

General Motors Sales Corporation, Diesel Engine Division
2130 W. 110th St., Cleveland, Ohio
Diesel Engine Equipment for Portable Electric Generator Sets, Direct Drive Power Units, Replacement Truck Engines, and Power Units for Haulage Equipment.

Goodyear Tire & Rubber Co.
Akron, Ohio
Belting (Conveyor, Elevator, Transmission), Hose (Air, Water, Steam, Suction, Miscellaneous), Chute Lining (Rubber)

Gruendler Crusher and Pulverizer Co.
2915 N. Market St., St. Louis, Mo.
Rock and Gravel Crushing and Screening Plants, Jaw Crushers, Roll Crushers, Hammer Mills, Lime Pulverizers

Hardinge Co., Inc.
York, Pa.
Scrubbers, Pulverizers, Dryers, Feeders, Classifiers, Washers, Thickeners

HarriSteel Products Co.
420 Lexington Avenue, New York, N. Y.
Woven Wire Screen Cloth and Abrasion Resisting Products

Hayward Co.
50 Church Street, New York City
Orange Peel Buckets, Clam Shell Buckets, Drag Line Buckets, Electric Motor Buckets, Automatic Take-up Reels

Hendrick Mfg. Co.
Carbondale, Pa.
Perforated Metal Screens, Perforated Plates for Vibrating and Shaking Screens, Elevator Buckets, Hendrick Vibrating Screens

Hercules Powder Co.
Wilmington, Del.
Explosives and Blasting Supplies

Illinois Powder Mfg. Co.
124 N. 4th St., St. Louis, Mo.
Gold Medal Explosives

International Harvester Co.
108 N. Michigan Ave., Chicago, Ill.
International Motor Trucks, International Industrial Tractors and Power Units

Iowa Manufacturing Co.
Cedar Rapids, Iowa
Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Hot and Cold Mix Asphalt Plants, Stabilizer Plants, KU-BIT Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment.

Kennedy-Van Saun Mfg. and Eng. Corp.
2 Park Ave., New York City
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Kensington Steel Co.
505 Kensington Ave., Chicago, Ill.
Manganese Steel Castings, Dipper Teeth, Crawler Treads, Jaw Plates, Concaves and Hammers

The King Powder Co., Inc.
Cincinnati, Ohio

Koehring Co.
3026 W. Concordia Ave., Milwaukee, Wis.
Mixers, Pavers, Shovels, Cranes, Draglines, Dumptors, Traildumps, Mud-Jacks

Kraft Bag Corporation
630 Fifth Ave., New York City
Multi-Wall and Heavy-Duty Paper Sacks, both Valve and Openmouth

Lima Locomotive Works, Inc.
Shovel and Crane Division
1108 Lima Trust Bldg., Lima, Ohio
Power Shovels, Draglines and Cranes

Link-Belt Co.
300 West Pershing Road, Chicago, Ill.
Complete Stone Preparation Plants. Conveyors, Elevators, Screens, Washing Equipment, Speed-o-Matic Shovels—Cranes—Draglines and Power Transmission Equipment

Ludlow-Saylor Wire Co.
Newstead Ave. & Wabash R. R., St. Louis, Mo.
Woven Wire Screens and Wire Cloth of Super-Loy, Manga-Loy and all commercial alloys and metals

Manganese Steel Forge Co. and Audubon Wire Cloth Corp.
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ROL-MAN Double Lock Mesh Manganese Steel Screens, Rolled and Forged Manganese Steel Products, Forgings, Pressings, Fabricated Products, Welding Rods, "AUDUBON" Wire Cloth in all Meshes and Metals and VIBRALOY Abrasion-Resisting Steel Screens, "METALWOVE" Spiral Woven Wire Conveyor Belts.

MANUFACTURERS' DIVISION of the NATIONAL CRUSHED STONE ASSOCIATION

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A Complete Line of Power Shovels, Draglines and Cranes

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Nordberg Mfg. Co.
Milwaukee, Wis.
Cone Crushers, Vibrating Screens, Classifiers, Diesel Engines, Steam Engines, Compressors, Mine Hoists, Underground Shovels, Track Maintenance Tools

Northern Blower Co.
65th St. South of Denison, Cleveland, Ohio
Dust Collecting Systems, Fans—Exhaust and Blowers

Northwest Engineering Co.
28 E. Jackson Blvd., Chicago, Ill.

Pettibone Mulliken Corp.
4710 West Division St., Chicago, Ill.

Pit and Quarry Publications
538 South Clark St., Chicago, Ill.
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Robins Conveying Belt Co.
Passaic, N. J.
Belt Conveyors, Bucket Elevators, Gyrex and Vibrex Screens, Feeders, Design and Construction of Complete Plants

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Ross Screen and Feeder Co.
19 Rector St., New York City
Ross Patent Chain Feeders for Feed Control of All Sizes Rock, Ores, Gravel, etc.

Screen Equipment Co.
9 Lafayette Ave., Buffalo, N. Y.
SECO Vibrating Screens

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screen, Simplicity D'centegrator, Simplicity D'watering Wheel

Smith Engineering Works
E. Capitol Drive at N. Holton Ave., Milwaukee, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stephens-Adamson Mfg. Co.
Aurora, Illinois
Complete Stone Preparation Plants, Conveying, Elevating, Screening, Transmission Equipment

W. O. & M. W. Talcott, Inc.
91 Sabin St., Providence, R. I.
Belt Fasteners

Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.
Manganese and other Special Alloy Steel Castings

The Texas Co.
135 E. 42nd St., New York City

The Thew Shovel Co.
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Power Shovels, Cranes, Crawler Cranes, Locomotive Cranes, Draglines. Diesel Electric, Gasoline. 3/8 to 2-1/2 cu. yd. capacities

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Allentown, Pa.
Stone Crushing, Gravel, Lime and Cement Machinery

Trojan Powder Co.
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Explosives and Blasting Supplies

The W. S. Tyler Co.
3615 Superior Ave., N. E., Cleveland, Ohio
Wire Screens, Screening Machinery, Scrubbers, Testing Sieves and Dryers

Warren Brothers Roads Co.
38 Memorial Drive, Cambridge, Mass.
Complete plants and separate plant units for bituminizing all types of stone, sand and gravel aggregate paving mixtures

Westinghouse Electric & Mfg. Co.
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Electric Motors and Control

Williams Patent Crusher and Pulverizer Co.
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Crushers, pulverizers, vibrating screens, air separators

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in

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January 20, 21, 22, 1941

INQUIRIES SHOULD BE DIRECTED TO

MANUFACTURERS' DIVISION
NATIONAL CRUSHED STONE ASSOCIATION

1735 14th STREET, N. W., WASHINGTON, D. C.